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(54) **METHOD AND APPARATUS FOR CONTROLLING A FUEL REFORMER BY USE OF EXISTING VEHICLE CONTROL SIGNALS**

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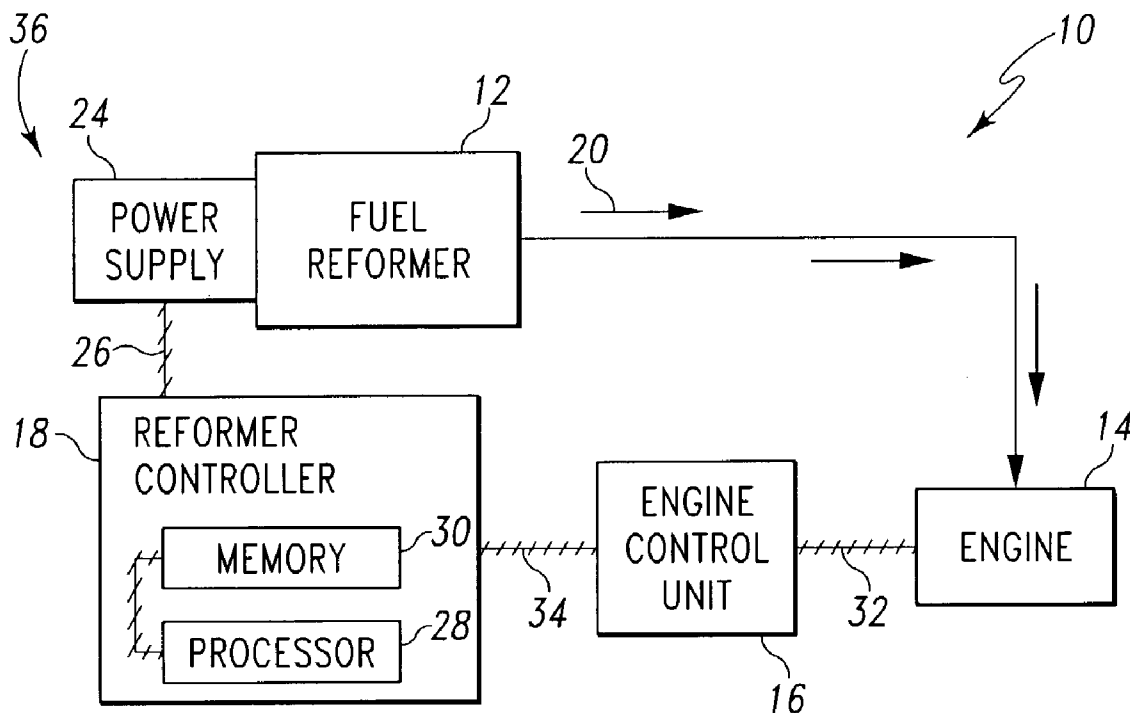
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(57) **ABSTRACT**

A reformer controller is electrically coupled to both a fuel reformer and an engine control unit. The reformer controller is configured to communicate with the engine control unit to monitor an engine load signal between the engine control unit and an internal combustion engine. The reformer controller operates the fuel reformer in response to the engine load signal. A method of operating a fuel reformer is also disclosed.

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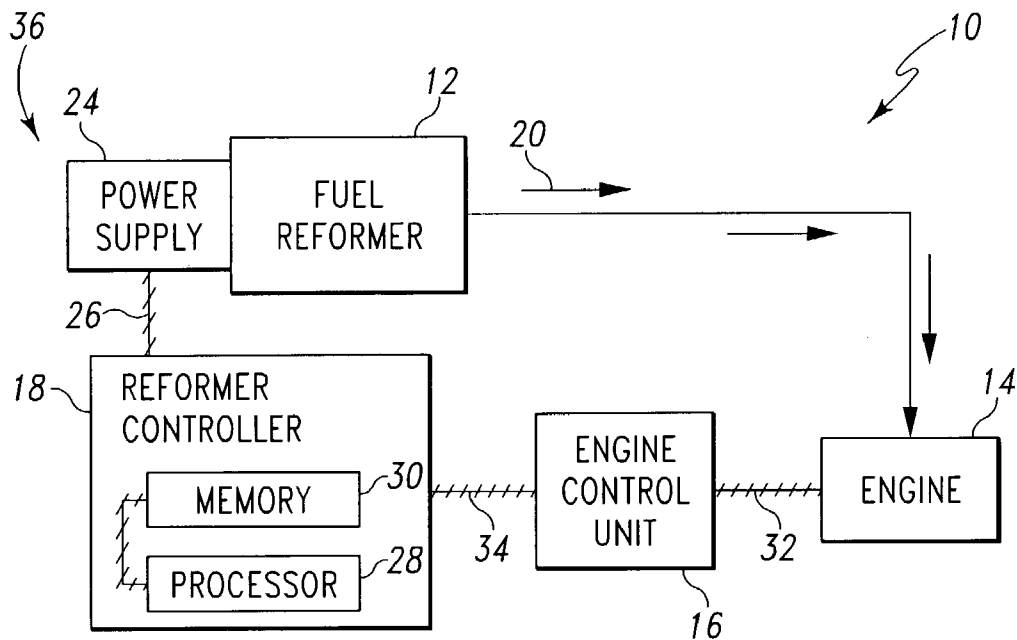


Fig. 1

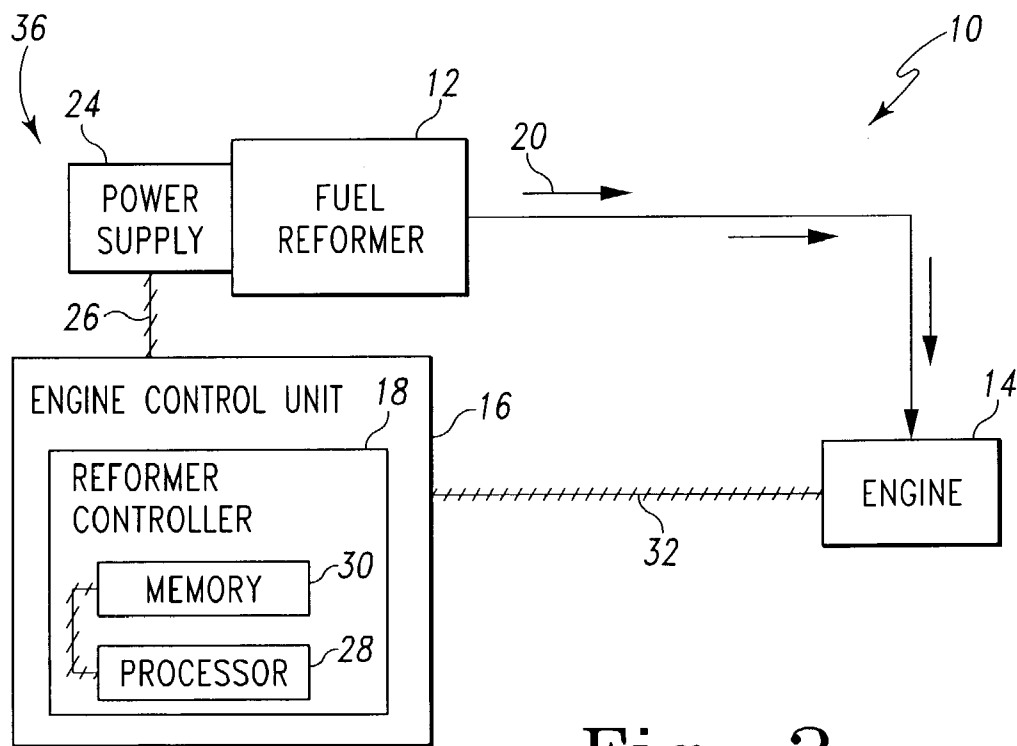


Fig. 2

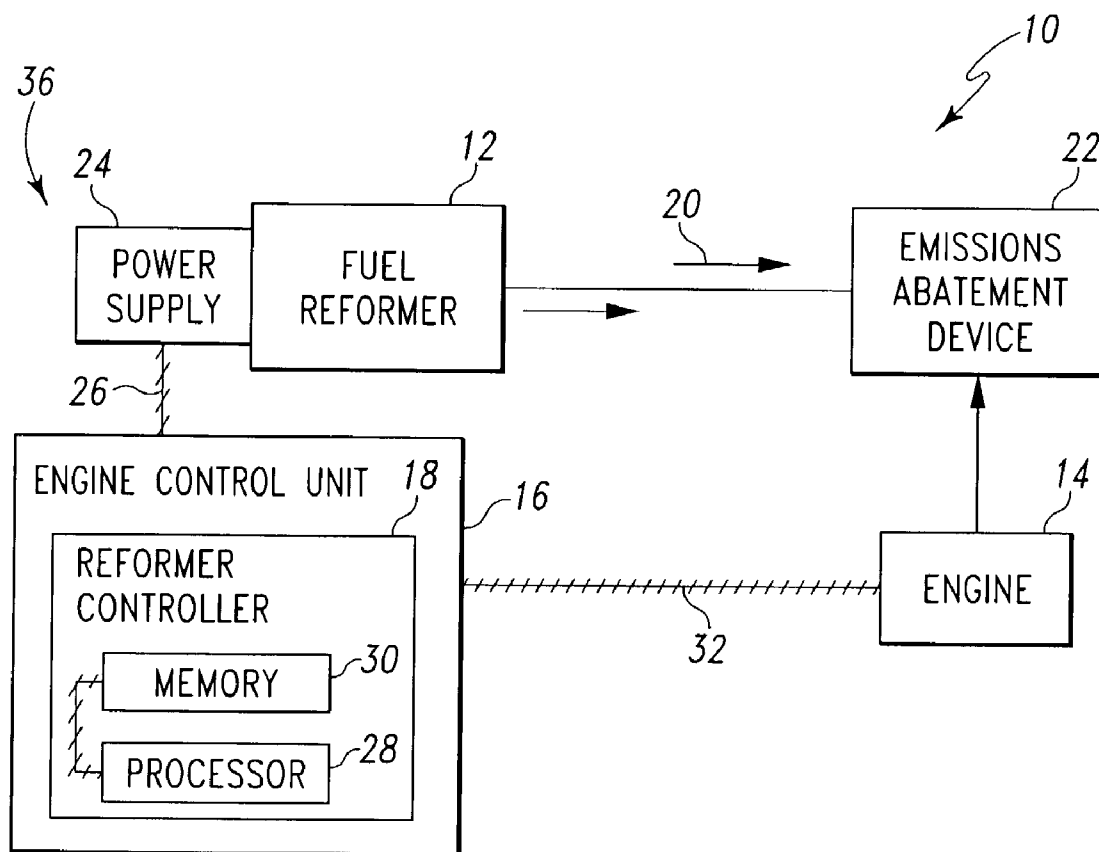


Fig. 3

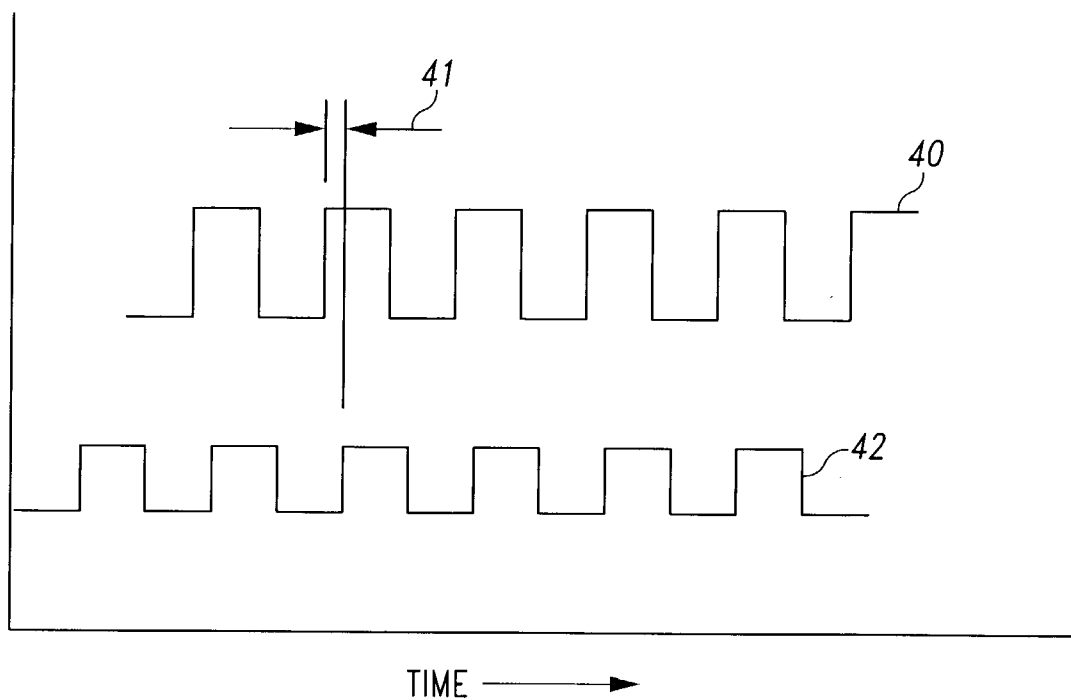


Fig. 4

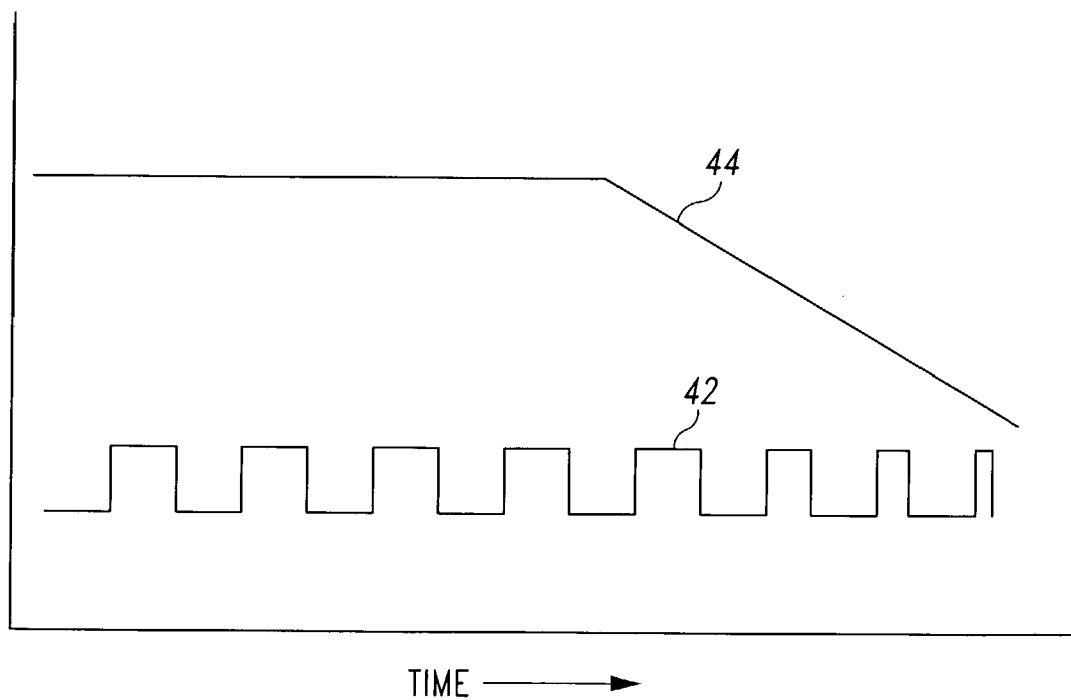


Fig. 5

## METHOD AND APPARATUS FOR CONTROLLING A FUEL REFORMER BY USE OF EXISTING VEHICLE CONTROL SIGNALS

### FIELD OF THE DISCLOSURE

[0001] The present disclosure relates to a control system for a fuel reformer, and more particularly to a fuel reformer control system operated by use of existing vehicle controls.

### BACKGROUND OF THE DISCLOSURE

[0002] Fuel reformers reform hydrocarbon fuel into a reformat gas such as hydrogen-rich gas. In the case of an onboard fuel reformer or a fuel reformer associated with a stationary power generator, the reformat gas produced by the fuel reformer may be utilized as fuel or fuel additive in the operation of an internal combustion engine. The reformat gas may also be utilized to regenerate or otherwise condition an emission abatement device associated with an internal combustion engine or as a fuel for a fuel cell.

### SUMMARY OF THE DISCLOSURE

[0003] According to one aspect of the present disclosure, there is provided a system having a reformer controller for controlling operation of a fuel reformer. The reformer controller monitors signals between an engine control unit and an internal combustion engine and executes a routine for controlling operation of the fuel reformer based on such signals. The fuel reformer may supply reformat gas to the internal combustion engine or an emissions abatement device, for example. Further, the reformer controller and engine control unit may be separate components, or the reformer controller may be integrated into the engine control unit such that a single hardware assembly is used to control both the fuel reformer and the engine, for example.

[0004] According to an illustrative embodiment, a method of operating a fuel reformer is provided. The method includes monitoring a signal between an internal combustion engine and an engine control unit and operating the fuel reformer in response to the signal between the engine and the engine control unit. The operating step includes adjusting an air-to-fuel ratio of an air/fuel mixture processed by the fuel reformer in response to the signal between the engine and the engine control unit.

[0005] In one embodiment, the monitoring step includes monitoring an ignition timing signal output from the engine control unit to the engine. The operating step further includes generating a reformer control signal based on the ignition timing signal and sending the reformer control signal to the fuel reformer. The generating step may include phase-shifting the ignition timing signal to create the reformer control signal.

[0006] In another embodiment, the monitoring step includes monitoring a throttle position signal sent from the engine to the engine control unit. Similarly, the operating step further includes generating a reformer control signal based on the throttle position signal and sending the reformer control signal to the fuel reformer. The generating step may include phase shifting the throttle position signal to create the reformer control signal to be received by the fuel reformer.

[0007] According to another illustrative embodiment, there is provided a system for operating a fuel reformer by

use of existing vehicle controls. The system includes a fuel reformer having an air/fuel input assembly and a reformer controller electrically coupled to an engine and to the air/fuel input assembly of the fuel reformer. The reformer controller includes a processing unit and a memory unit electrically coupled to the processing unit. The memory unit has stored therein a plurality of instructions which, when executed by the processing unit, causes the processing unit to (i) monitor a signal between the engine and an engine control unit and (ii) operate the fuel reformer in response to the signal between the engine and the engine control unit.

[0008] The signal may be an ignition timing signal sent from the engine control module to the engine or a throttle position signal sent from the engine to the engine control module, for example. The memory unit may also cause the processing unit to phase shift the signal to create a reformer control signal to be sent to the fuel reformer for operation thereof.

[0009] According to still another illustrative embodiment, there is provided a method of operating a fuel reformer. The method includes monitoring a load of an engine and generating a load signal based on thereon, and operating the fuel reformer based on the load signal.

[0010] The above and other features of the present disclosure will become apparent from the following description and the attached drawings.

### BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. 1 is a simplified block diagram of a power system having a fuel reformer, a reformer controller to operate the fuel reformer, and an engine control unit to operate an internal combustion engine of the system, and further showing the reformat gas produced by the fuel reformer supplied to the engine;

[0012] FIG. 2 is a simplified block diagram similar to FIG. 1 except that the reformer controller is integrated into the engine control unit;

[0013] FIG. 3 is a simplified block diagram similar to FIG. 2 showing a power system in which the reformat gas produced by the fuel reformer is supplied to an emissions abatement device;

[0014] FIG. 4 is a graph showing an illustrative ignition timing signal sent from the engine control unit to the engine, and also showing an illustrative reformer control signal below the ignition timing signal which was generated by the reformer controller from the ignition timing signal; and

[0015] FIG. 5 is a graph showing an illustrative throttle position signal which is output from the engine to the engine control unit, and also showing another pulsed reformer control signal generated from the throttle position signal.

### DETAILED DESCRIPTION OF THE DRAWINGS

[0016] While the concepts of the present disclosure are susceptible to various modifications and alternative forms, specific exemplary embodiments thereof have been shown by way of example in the drawings and will herein be described in detail. It should be understood, however, that there is no intent to limit the disclosure to the particular forms disclosed, but on the contrary, the intention is to cover

all modifications, equivalents, and alternatives following within the spirit and scope of the invention as defined by the appended claims.

[0017] Referring to FIG. 1, there is shown an illustrative power system 10 including a fuel reformer 12, an internal combustion engine 14, and an engine control unit 16. As will be described herein in greater detail, fuel reformer 12 using information obtained from engine control unit 16. Internal combustion engine 14 may be embodied as any type of internal combustion engine including, for example, a spark-ignited gasoline engine, a diesel engine, a natural gas engine, or the like. The internal combustion engine 14 produces mechanical output which is utilized to drive or otherwise mechanically power a driven mechanism (not shown) such as a transmission, specifically a vehicle transmission, which is utilized to propel a vehicle or a power generator or the like for producing electrical power.

[0018] System 10 further includes a reformer controller 18 for controlling the operation of fuel reformer 12. Illustratively, fuel reformer 12 supplies reformat gas 20 to the intake manifold of the engine 14 for use as a fuel or fuel additive, for example. However, it is within the scope of this disclosure for fuel reformer 12 to supply reformat gas 20 to various other components such as an emissions abatement device 22 (shown in FIG. 3), a fuel cell (not shown), etc.

[0019] As shown in FIG. 1, the reformer controller 18 and the engine control unit 16 are discrete components separate from each other. It should be appreciated, however, that the reformer controller 18 may be integrated into an engine control unit 16, as shown in FIG. 2. In such a way, a single hardware assembly may be utilized to control both the fuel reformer 12 and the engine 14. Further, as shown in FIGS. 1-3, there are shown specific exemplary implementations of the power system 10. In the embodiments shown in FIGS. 1 and 2, the output from the fuel reformer 12 (i.e., reformat gas 20) is supplied to the intake of the engine 14, whereas in the embodiment shown in FIG. 3, the output from fuel reformer 12 is supplied to an emissions abatement device 22 such as a NOx absorber or a soot filter, for example.

[0020] As mentioned above, operation of fuel reformer 12 is based on a number of existing vehicle operating parameters. Conventionally, these existing vehicle operating parameters are monitored by engine control unit 16 through the use of known sensors (not shown), for example, coupled to engine 14. Therefore, it may not be necessary to provide direct communication between reformer controller 18 and engine 14 using various additional sensors to obtain this same data to be used to operate fuel reformer 12. The present disclosure, therefore, provides that reformer controller 18 uses existing information about the operational diagnostics of engine 14 which is readily obtained from engine control unit 16. As shown in FIG. 1, controller 18 of system 10 obtains or collects its data directly from the engine control unit 16 via a signal line 34 between reformer controller 18 and engine control unit 16, as is discussed in more detail below. Therefore, the existing vehicle systems are also effectively monitored by the reformer controller 18 which allows reformer controller 18 to assess the information as it is gathered and provide a calculated response to such parameters to vary or adjust the operation of fuel reformer 12 as necessary. This use of existing vehicle control signals to control fuel reformer 12 reduces the number of discrete

sensors that must be added to a preexisting system when modifying that system to include a fuel reformer, such as fuel reformer 12, for example.

[0021] In addition to obtaining information from engine control unit 16, controller 18 may also obtain control information associated with other vehicle parameters from any other system on the vehicle, including passive and mechanical controls, for example. The controller 18 generates a calculated response to such input in order to adjust the operation of the fuel reformer 12 to meet the changing needs of system 10. As mentioned above, reformer controller 18 may be either a separate component of system 10 in communication with engine control unit 16 along signal line 34, as shown in FIG. 1, or reformer controller 18 may be incorporated into an existing engine control unit 16 as shown in FIG. 2, for example. A similar illustrative power system disclosing an integrated electronic control unit for controlling both a fuel reformer and an internal combustion engine of the power system is shown and described in commonly-assigned U.S. patent application Ser. No. 10/245,268. This application is hereby incorporated by reference herein.

[0022] Specifically, controller 18 of power system 10 monitors existing output signals of engine 14 to unit 16 as well as existing input signals from unit 16 to engine 14. For example, controller 18 monitors any information or data which may be used to determine engine load, such as ignition timing and throttle position, for example. This information is then used in a calculated response to control the operation of fuel reformer 12.

[0023] Referring back to FIG. 1, a passageway (not shown) connects fuel reformer 12 with the intake of engine 14. Fuel reformer 12 reforms (i.e., converts) hydrocarbon fuel into reformat gas 20 that includes, among other things, hydrogen and carbon monoxide. Reformat gas 20 is conducted through the passageway to engine 14 so that reformat gas 20 may be used to operate engine 14 more efficiently and reduce various engine emissions, for example.

[0024] Fuel reformer 12 may be embodied as any type of fuel reformer, such as, for example, a catalytic fuel reformer, a thermal fuel reformer, a steam fuel reformer, or any other type of partial oxidation fuel reformer. Fuel reformer 12 may also be embodied as a plasma fuel reformer. A plasma fuel reformer uses plasma to convert a mixture of air and hydrocarbon fuel into a reformat gas rich in hydrogen and carbon monoxide. Systems including plasma fuel reformers are disclosed in U.S. Pat. No. 5,425,332 issued to Rabinovich et al.; U.S. Pat. No. 5,437,250 issued to Rabinovich et al.; U.S. Pat. No. 5,409,784 issued to Bromberg et al.; and U.S. Pat. No. 5,887,554 issued to Cohn, et al., the disclosures of which are hereby incorporated by reference.

[0025] As shown in FIG. 1, fuel reformer 12 and its associated components are under the control of reformer controller 18. In particular, components such as temperature, pressure, or gas composition sensors (not shown), a fuel inlet assembly such as a fuel injector (not shown), and air inlet valve(s) (not shown) are each electrically coupled to the reformer controller 18. Moreover, a power supply 24 is electrically coupled to the reformer controller 18 via a signal line 26. Although signal line 26 is shown schematically as a single line, it should be appreciated that signal line 26, along

with the signal line(s) associated with each of the other components of system 10, for example, may be configured as any type of signal carrying assembly which allows for the transmission of electrical signals in either one or both directions between the reformer controller 18 and the corresponding component.

[0026] For example, any one or more of the signal lines may be embodied as a wiring harness having a number of signal lines which transmit electrical signals between the reformer controller 18 and the corresponding component. It should be appreciated that any number of other wiring configurations may also be used. For example, individual signal wires may be used, or a system utilizing a signal multiplexer may be used for the design of any one or more of the signal lines. Moreover, the signal lines may be integrated such that a single harness or system is utilized to electrically couple some or all of the components associated with fuel reformer 12 to reformer controller 18.

[0027] The reformer controller 18 is, in essence, the master computer responsible for interpreting electrical signals sent by sensors associated with the fuel reformer 12 and for activating electronically-controlled components associated with the fuel reformer 12 in order to control the fuel reformer 12. For example, the reformer controller 18 of the present disclosure is operable to, amongst many other things, actuate or shutdown the fuel reformer 12, determine the beginning and end of each injection cycle of fuel into the fuel reformer 12, calculate and control the amount and ratio of air and fuel to be introduced into the fuel reformer 12, determine the temperature of the fuel reformer 12, and determine the power level to supply to the fuel reformer 12.

[0028] To do so, the reformer controller 18 includes a number of electronic components commonly associated with electronic units which are utilized in the control of electromechanical systems. For example, the reformer controller 18 may include, amongst other components customarily included in such devices, a processor such as a microprocessor 28 and a memory device 30 such as a programmable read-only memory device ("PROM") including erasable PROM's (EPROM's or EEPROM's). The memory device 30 is provided to store, amongst other things, instructions in the form of, for example, a software routine (or routines) which, when executed by the microprocessor 28, allows the reformer controller 18 to control operation of the fuel reformer 12.

[0029] The reformer controller 18 also includes an analog interface circuit (not shown). The analog interface circuit converts the output signals from the various fuel reformer sensors into a signal which is suitable for presentation to an input of the microprocessor 28. In particular, the analog interface circuit, by use of an analog-to-digital (A/D) converter (not shown) or the like, converts the analog signals generated by the sensors into a digital signal for use by the microprocessor 28. It should be appreciated that the A/D converter may be embodied as a discrete device or number of devices, or may be integrated into the microprocessor. It should also be appreciated that if any one or more of the sensors associated with the fuel reformer 12 generate a digital output signal, the analog interface circuit may be bypassed.

[0030] Similarly, the analog interface circuit converts signals from the microprocessor 28 into an output signal which

is suitable for presentation to the electrically-controlled components associated with the fuel reformer 12 (e.g., the power supply 24). In particular, the analog interface circuit, by use of a digital-to-analog (D/A) converter (not shown) or the like, converts the digital signals generated by the microprocessor 28 into analog signals for use by the electronically-controlled components associated with the fuel reformer 12 such as the power supply 24. It should be appreciated that, similar to the A/D converter described above, the D/A converter may be embodied as a discrete device or number of devices, or may be integrated into the microprocessor 28. It should also be appreciated that if any one or more of the electronically-controlled components associated with the fuel reformer 12 operate on a digital input signal, the analog interface circuit may be bypassed.

[0031] Hence, the reformer controller 18 may be operated to control operation of the fuel reformer 12. In particular, the reformer controller 18 executes a routine including, amongst other things, a closed-loop control scheme in which the reformer controller 18 monitors outputs of the sensors (not shown) associated with the fuel reformer 12 as well as various signals sent between engine 14 and engine control unit 16 in order to control the inputs to the electronically-controlled components associated therewith. To do so, the reformer controller 18 communicates with the sensors associated with the fuel reformer 12 in order to determine, amongst numerous other things, the amount, temperature, and/or pressure of air and/or fuel being supplied to the fuel reformer 12, the amount of oxygen in the reformat gas, the temperature of the reformat gas being produced thereby, and the composition of the reformat gas. Armed with this data as well as data obtained from engine control unit 16 regarding the operating parameters of engine 14, the reformer controller 18 performs numerous calculations each second, including looking up values in preprogrammed tables, in order to execute algorithms to perform such functions as determining when or how long the fuel reformer's fuel injector or other fuel input device is opened, controlling the power level input to the fuel reformer, controlling the amount of air advanced through the air inlet valve(s), etcetera.

[0032] As mentioned above, reformer controller 18 is electrically coupled to power supply 24 along signal line 26. As such, the reformer controller 18 communicates with the power supply 24 to selectively operate and shutdown the fuel reformer 12. Collectively, the fuel reformer 12 and the reformer controller 18 define a fuel reformer system 36 which, among other uses, may be used in the construction of an onboard system for a vehicle or a stationary power generator.

[0033] The engine 14, on the other hand, is under the control of engine control unit 16. In particular, engine systems, such as vehicle systems for use in the design of a stationary power generator, include an engine control unit which is, in essence, the master computer responsible for interpreting electrical signals sent by engine sensors and for activating electronically-controlled engine components to control the engine. For example, an engine control unit is operable to, amongst many other things, determine the ignition timing, the throttle position, the beginning and end of each injection cycle of each cylinder, or determine both fuel metering and injection timing in response to sensed

parameters such as engine crankshaft position and rpm, engine coolant and intake air temperature, and absolute intake air boost pressure.

[0034] In particular, the engine control unit 16 is electrically coupled to a number of electronically-controlled components associated with the engine 14 (e.g., a fuel injector assembly, ignition assembly, etcetera) via a signal line 32. As with the signal lines associated with the fuel reformer 12, the signal line 32 may be any type of signal carrying connector including a wiring harness for carrying the electrical signals associated with numerous engine components.

[0035] In particular, as mentioned above, illustrative power system 10 uses information based on the load of the engine 14 to operate fuel reformer 12. The amount of reformat gas 20 required to efficiently operate engine 14 is based, at least in part, on the load which is placed on engine 14 due to other operational factors. Therefore, information known to engine control unit 16 relating to the load of engine 14 is sent to reformer controller 18.

[0036] For example, an ignition timing signal is an output of engine control unit 16 that is sent to engine 14 along signal line 32 to allow engine control unit 16 to properly control and operate engine 14. This pulsed signal varies in response to the load placed on engine 14. Therefore, this signal may be used by reformer controller 18 to operate fuel reformer 12. For example, an illustrative pulsed ignition timing signal 40 is shown in FIG. 4 along with an illustrative phase-shifted reformer control signal 42 used to operate fuel reformer 12. Microprocessor 28 of controller 18 monitors ignition timing signal 40 and generates reformer control signal 42 based on ignition timing signal 40. It is within the scope of this disclosure to phase-shift or manipulate ignition timing signal 40 as necessary to create a reformer control signal for appropriately controlling fuel reformer 12 based on the needs of system 10. As shown in FIG. 4, such phase shifting of reformer control signal 42 is represented by reference numeral 41. Such manipulation of the ignition timing signal 40 may be accomplished by performing a phase-shifting calculation using, for example, a monostable multi-vibrator, a pulse stretcher, a pulse coder, etc. to phase shift the fuel reformer 12 operation based on such ignition timing signal 40. Reformer control signal 42 may also be configured to have a different frequency or amplitude than that of the ignition timing signal 40.

[0037] Further, a throttle position signal 44 is also indicative of engine load and may be used to generate an appropriate reformer control signal in response thereto. Throttle position signal 44 is a signal normally input into engine control unit 16 from engine 14. Illustrative throttle position signal 44 is shown in FIG. 5 as a linear analog signal. Illustrative reformer signal 42, generated by reformer controller 18 in response to throttle position signal 44, is a pulsed signal and is shown below the linear throttle position signal 44. In other words, throttle position signal 44, sent along signal line 32 from engine 14 to engine control unit 16, is read by reformer controller 18, and manipulated by reformer controller 18 to generate reformer control signal 42. Reformer control signal 42 is then sent along signal line 26 to power supply 24, associated with fuel reformer 12, to effectively control the operation of fuel reformer 12. Illustrative throttle position signal 44 may remain steady or may change, as shown in FIG. 5, according to torque or other

operating characteristics of the engine. The control pulses of the reformer control signal 42 may be altered (e.g. the length or duty cycle thereof) in response to such changes in the throttle position over time.

[0038] Therefore, as described above, fuel reformer 12 is operated through the use of existing vehicle control signals, such as ignition timing signal 40 and throttle position signal 44, for example. Reformer controller 18 may monitor other signals received by engine control unit 16 and/or sent from engine control unit 16 to control the operation of fuel reformer 12 as well. For example, other signals bearing engine load information are monitored and manipulated to generate reformer signal 42.

[0039] While the concepts of the present disclosure have been illustrated and described in detail in the drawings and foregoing description, such an illustration and description is to be considered as exemplary and not restrictive in character, it being understood that only the illustrative embodiments have been shown and described and that all changes and modifications that come within the spirit of the disclosure are desired to be protected.

[0040] There are a plurality of advantages of the concepts of the present disclosure arising from the various features of the systems described herein. It will be noted that alternative embodiments of each of the systems of the present disclosure may not include all of the features described yet still benefit from at least some of the advantages of such features. Those of ordinary skill in the art may readily devise their own implementations of a system that incorporate one or more of the features of the present disclosure and fall within the spirit and scope of the invention as defined by the appended claims.

1. A method of operating a fuel reformer, the method comprising the steps of:

monitoring a signal between an internal combustion engine and an engine control unit, and

operating the fuel reformer in response to the signal between the engine and the engine control unit.

2. The method of claim 1, wherein the operating step comprises adjusting an air-to-fuel ratio of an air/fuel mixture processed by the fuel reformer in response to the signal between the engine and the engine control module.

3. The method of claim 1, wherein the monitoring step further comprises monitoring an ignition timing signal output from the engine control module to the engine.

4. The method of claim 3, wherein the operating step includes generating a reformer control signal based on the ignition timing signal and sending the reformer control signal to the fuel reformer.

5. The method of claim 4, wherein the generating step includes phase-shifting the ignition timing signal to create the reformer control signal.

6. The method of claim 1, wherein the monitoring step further comprises monitoring a throttle position signal input into the engine control unit from the engine.

7. The method of claim 6, wherein the operating step includes generating a reformer control signal based on the throttle position signal and sending the reformer control signal to the fuel reformer.



8. A method of operating a fuel reformer, the method comprising the steps of:

monitoring an engine load signal based load of an internal combustion engine,

generating a reformer control signal based on the engine load signal; and

operating the fuel reformer based on the reformer signal.

9. The method of claim 8, wherein the engine load signal is an ignition timing signal sent from an engine control unit of the system to the engine.

10. The method of claim 8, wherein the engine load signal is a throttle position signal sent from the engine to an engine control unit of the system.

11. The method of claim 8, wherein the step of generating a reformer control signal includes phase-shifting the engine load signal.

12. A power system comprising:

a fuel reformer,

an engine control unit coupled to an engine, and

a controller electrically coupled to both the fuel reformer and the engine control unit wherein the controller comprises (i) a processor, and (ii) a memory device electrically coupled to the processor, the memory

device having stored therein a plurality of instructions which, when executed by the processor, causes the processor to:

(a) monitor a signal between the engine control unit and the engine; and

(b) operate the fuel reformer based on the signal between the engine control unit and the engine.

13. The power system of claim 12, wherein the signal between the engine control unit and the engine is an ignition timing signal sent from the engine control unit to the engine.

14. The power system of claim 13, wherein the plurality of instructions, when executed by the processor, further cause the processor to generate a reformer control signal based on the ignition timing signal.

15. The power system of claim 12, wherein the signal between the engine control unit and the engine is a throttle position signal sent from the engine to the engine control unit.

16. The power system of claim 15, wherein the plurality of instructions, when executed by the processor, further cause the processor to generate a reformer control signal based on the throttle position signal.

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